# General

## Guideline Title

ACR Appropriateness Criteria® cerebrovascular disease.

## Bibliographic Source(s)

De La Paz RL, Wippold FJ II, Cornelius RS, Amin-Hanjani S, Angtuaco EJ, Broderick DF, Brown DC, Creasy JL, Davis PC, Garvin CF, Hoh BL, McConnell CT Jr, Mechtler LL, Seidenwurm DJ, Smirniotopoulos JG, Tobben PJ, Waxman AD, Zipfel GJ, Expert Panel on Neurologic Imaging. ACR Appropriateness CriteriaÂ® cerebrovascular disease. [online publication]. Reston (VA): American College of Radiology (ACR); 2011. 23 p. [131 references]

## Guideline Status

Note: This guideline has been updated. The National Guideline Clearinghouse (NGC) is working to update this summary.

# Recommendations

## Major Recommendations

Note: This guideline has been updated. The National Guideline Clearinghouse (NGC) is working to update this summary. The recommendations that follow are based on the previous version of the guideline.

ACR Appropriateness Criteria®

Clinical Condition: Cerebrovascular Disease

Variant 1: Asymptomatic. Structural lesion on physical examination (cervical bruit) and/or risk factors.

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| US carotid with Doppler | 8 | May need to confirm with second noninvasive study. | O |
| MRA neck without contrast | 8 | | O |
| MRA neck without and with contrast | 8 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| CTA neck with and/or without contrast | 4,5,6 May be appropriate; 7,8,9 Usually appropriate | Multidetector CTA has higher spatial resolution than MRA with no flow artifact and better visualization of plaque calcium. May show late-filling "string" sign of | ☢☢☢ Relative Radiation Level |

Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate

*RRL: Relative Radiation Level

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| | | severe ICA stenosis better than MRA. (Axial source images and reformatted maximum-intensity-projection [MIP] images preferred; 3D surface reformations may create misleading artifacts.) See the Relative Radiation Level Information section for important radiation dose warning with multiple or repeated CT procedures. | |
| MRI head without contrast | 5 | | O |
| MRI head without and with contrast | 5 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| CT head without contrast | 5 | | ☢☢☢ |
| CT head with contrast | 5 | | ☢☢☢ |
| CT head without and with contrast | 3 | | ☢☢☢ |
| US transcranial with Doppler | 3 | | O |
| MRA head without contrast | 3 | | O |
| MRA head without and with contrast | 3 | | O |
| CTA head with contrast | 3 | May be useful if ICA stenosis found. See the Relative Radiation Level Information section for important radiation dose warning with multiple or repeated CT procedures. | ☢☢☢ |
| Arteriography neck | 2 | | ☢☢☢ |
| Arteriography cervicocerebral | 2 | | ☢☢☢ |
| $^{15}$O-PET head | 2 | $^{15}$O-PET may identify tissue at risk of ischemic injury with $CMRO_2$ and OEF images. | ☢☢☢ |
| Tc-99m HMPAO SPECT head | 2 | Consider cerebral blood flow with acetazolamide challenge to assess CVR. | ☢☢☢☢ |
| CT head perfusion with contrast | 2 | See the Relative Radiation Level Information section for important radiation dose warning with multiple or repeated CT procedures. | ☢☢☢ |
| MRI functional (fMRI) head without contrast | 1 | | O |
| MR spectroscopy head without contrast | 1 | | O |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation Level |

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 2: Carotid territory or vertebrobasilar TIA, initial screening survey. (In these tables a TIA is the report of an historical transient ischemic event by the patient or other witness. The acute neurological deficit in progress must be treated as an acute stroke and can only be considered a TIA in retrospect if it resolves without intervention.)

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| MRI head without contrast | 8 | | O |
| MRI head without and with contrast | 8 | See statement regarding contrast in text under | O |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation |

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| MRA head and neck without contrast | 8 | "Anticipated Exceptions." | O |
| MRA head and neck without and with contrast | 8 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| CT head without contrast | 8 | | ☢☢☢ |
| CT head with contrast | 8 | | ☢☢☢ |
| CTA head and neck with contrast | 8 | Combined vascular and cerebral evaluation should be considered. MRI with DWI preferred if treatment not unreasonably delayed. See the Relative Radiation Level Information section for important radiation dose warning with multiple or repeated CT procedures. | ☢☢☢ |
| CT head perfusion with contrast | 6 | If directly employed in decision making and planning treatment. Appropriate if stenosis or occlusion found. Consider acetazolamide challenge to assess CVR if >24 hours since TIA. See the Relative Radiation Level Information section for important radiation dose warning with multiple or repeated CT procedures. | ☢☢☢ |
| US carotid with Doppler | 6 | | O |
| CT head without and with contrast | 3 | | ☢☢☢ |
| US transcranial with Doppler | 3 | | O |
| Arteriography neck | 3 | | ☢☢☢ |
| Arteriography cervicocerebral | 3 | | ☢☢☢ |
| MRI functional (fMRI) head without contrast | 1 | | O |
| MR spectroscopy head without contrast | 1 | | O |
| $^{15}$O-PET head | 1 | | ☢☢☢ |
| Tc-99m HMPAO SPECT head | 1 | May be useful with acetazolamide for evaluating CVR for suspected TIA when MRI or CT is inconclusive. | ☢☢☢☢ |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation Level |

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 3: New focal neurologic defect, fixed or worsening. Less than 3 hours.

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | CT to exclude intracranial hemorrhage is needed prior to rtPA thrombolytic therapy (FDA, JCAHO, and ASA recommendations). Delaying or withholding rtPA thrombolysis in the 3-hour window after symptom onset based on multimodality MRI (DWI, PWI, gradient echo [GRE] or MRA) or CT (CTP or CTA) may not be medically appropriate. See the Relative Radiation Level Information section for important radiation dose warning with multiple or | *Relative Radiation Level |

| Radiologic Procedure | Rating | repeated CT procedures.<br>Comments | RRL* |
|---|---|---|---|
| MRI head without contrast | 8 | | O |
| MRI head without or with contrast | 8 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| MRA head and neck without contrast | 8 | | O |
| MRA head and neck without and with contrast | 8 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| CT head with contrast | 8 | Combined vascular and cerebral evaluation should be considered. MRI with DWI preferred if thrombolytic treatment not delayed or withheld. See the Relative Radiation Level Information section for important radiation dose warning with multiple or repeated CT procedures. | ☢☢☢ |
| CTA head and neck with contrast | 8 | Combined vascular and cerebral evaluation should be considered. MRI with DWI preferred if thrombolytic treatment not delayed or withheld. See the Relative Radiation Level Information section for important radiation dose warning with multiple or repeated CT procedures. | ☢☢☢ |
| CT head perfusion with contrast | 6 | In this scenario, CTP and CTA are equally useful and can be obtained together (with two injections on most scanners or one injection on volume CT) (but should not delay rtPA therapy decision). If CT is used for planning treatment such as thrombectomy. Appropriate if stenosis or occlusion found. See the Relative Radiation Level Information section for important radiation dose warning with multiple or repeated CT procedures. | ☢☢☢ |
| Arteriography neck | 5 | If intra-arterial therapy is considered. | ☢☢☢ |
| Arteriography cervicocerebral | 5 | If intra-arterial therapy is considered. | ☢☢☢ |
| CT head without and with contrast | 3 | | ☢☢☢ |
| US carotid with Doppler | 2 | | O |
| US transcranial with Doppler | 2 | | O |
| MRI functional (fMRI) head without contrast | 1 | | O |
| MR spectroscopy head without contrast | 1 | | O |
| $^{15}$O-PET head | 1 | | ☢☢☢ |
| Tc-99m HMPAO SPECT head | 1 | | ☢☢☢☢ |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation Level |

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 4: New focal neurologic defect, fixed or worsening. Three to 24 hours.

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| MRI head without contrast | 8 | | O |
| MRI head without and with contrast | 8 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| MRA head and neck without contrast | 8 | | O |
| MRA head and neck without and with contrast | 8 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| CT head without contrast | 8 | | ☢☢☢ |
| CT head with contrast | 8 | | ☢☢☢ |
| CTA head and neck with contrast | 8 | Combined vascular and cerebral evaluation should be considered. MRI preferred if treatment not unreasonably delayed. See the Relative Radiation Level Information section for important radiation dose warning with multiple or repeated CT procedures. | ☢☢☢ |
| CT head perfusion without contrast | 6 | In this scenario, CTP and CTA are equally useful and can be obtained together (with two injections on most scanners or one injection on volume CT). If CT is used for planning treatment such as thrombectomy within 8 hours of symptom onset. Appropriate if stenosis or occlusion found. See the Relative Radiation Level Information section for important radiation dose warning with multiple or repeated CT procedures. | ☢☢☢ |
| Arteriography neck | 6 | If intra-arterial therapy is considered. | ☢☢☢ |
| Arteriography cervicocerebral | 6 | If intra-arterial therapy is considered. | ☢☢☢ |
| CT head without and with contrast | 3 | | ☢☢☢ |
| US carotid with Doppler | 2 | | O |
| US transcranial with Doppler | 2 | | O |
| MRI functional (fMRI) head without contrast | 1 | | O |
| MR spectroscopy head with contrast | 1 | | O |
| $^{15}$O-PET head | 1 | | ☢☢☢ |
| Tc-99m HMPAO SPECT head | 1 | | ☢☢☢☢ |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation Level |

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 5: New focal neurologic defect, fixed or worsening. Longer than 24 hours.

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| MRI head without contrast | 8 | | O |
| MRI head without and with contrast | 8 | See statement regarding contrast in text under "Anticipated Exceptions." | O |

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| MRA head and neck without contrast | 8 | | O |
| MRA head and neck without and with contrast | 8 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| CT head without contrast | 8 | | ☢☢☢ |
| CT head with contrast | 8 | | ☢☢☢ |
| CTA head and neck with contrast | 8 | Combined vascular and cerebral evaluation should be considered. MRI with DWI preferred if treatment not unreasonably delayed. See the Relative Radiation Level Information section for important radiation dose warning with multiple or repeated CT procedures. | ☢☢☢ |
| Arteriography neck | 6 | If intra-arterial therapy is considered. | ☢☢☢ |
| Arteriography cervicocerebral | 6 | If intra-arterial therapy is considered. | ☢☢☢ |
| CT head perfusion with contrast | 5 | If used for decision making or planning treatment such as angioplasty and stenting. Appropriate if stenosis or occlusion found. Consider acetazolamide challenge to assess CVR. See the Relative Radiation Level Information section for important radiation dose warning with multiple or repeated CT procedures. | ☢☢☢ |
| CT head without and with contrast | 3 | | ☢☢☢ |
| US carotid with Doppler | 2 | | O |
| US transcranial with Doppler | 2 | | O |
| MRI functional (fMRI) head without contast | 1 | | O |
| MR spectroscopy head without contrast | 1 | | O |
| $^{15}$O-PET head | 1 | | ☢☢☢ |
| Tc-99m HMPAO SPECT head | 1 | May be useful with acetazolamide for evaluating CVR for suspected TIA when MRI or CT is inconclusive. | ☢☢☢☢ |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation Level |

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 6: Risk of unruptured aneurysm. Positive family history.

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| CTA head with contrast | 8 | Multidetector CTA has higher spatial resolution than MRA with no flow artifact. (Axial source images and reformatted MIP images preferred; 3D surface reformations may create misleading artifacts). Radiation exposure and slightly greater risk of contrast toxicity/reaction compared to contrast MRA. NCCT obtained routinely at the same time. MRA preferred if treatment is not unreasonably delayed. | ☢☢☢ |
| MRA head without contrast | 7 | | O |

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| MRA head without and with contrast | 7 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| MRI head without contrast | 6 | | O |
| MRI head without and with contrast | 6 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| MRA neck without contrast | 3 | | O |
| MRA neck without and with contrast | 3 | | O |
| CT head without contrast | 3 | | ☢☢☢ |
| CT head with contrast | 3 | | ☢☢☢ |
| CT head without and with contrast | 3 | | ☢☢☢ |
| CTA neck with contrast | 2 | | ☢☢☢ |
| US carotid with Doppler | 1 | | O |
| US transcranial with Doppler | 1 | | O |
| Arteriography neck | 1 | | ☢☢☢ |
| Arteriography cervicocerebral | 1 | | ☢☢☢ |
| MRI functional (fMRI) head without contrast | 1 | | O |
| MR spectroscopy head without contrast | 1 | | O |
| $^{15}$O-PET head | 1 | | ☢☢☢ |
| Tc-99m HMPAO SPECT head | 1 | | ☢☢☢☢ |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation Level |

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 7: Clinically suspected subarachnoid hemorrhage (SAH), not yet confirmed.

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| CT head without contrast | 9 | | ☢☢☢ |
| CT head without and with contrast | 5 | If CTA done. | ☢☢☢ |
| CT head with contrast | 5 | | ☢☢☢ |
| MRI head without contrast | 5 | | O |
| MRI head without and with contrast | 5 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| CTA head with contrast | 5 | If NCCT positive for SAH, add CTA for aneurysm detection and surgical/catheter treatment planning. Not usually used for initial evaluation without confirmed SAH. | ☢☢☢ |
| MRA head without contrast | 4 | | O |
| MRA head without and with contrast | 4 | See statement regarding contrast in text under | O |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation |

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| Arteriography neck | 2 | "Anticipated Exceptions." | ☢☢☢ |
| Arteriography cervicocerebral | 2 | | ☢☢☢ |
| MRA neck without contrast | 2 | | O |
| MRA neck without and with contrast | 2 | | O |
| CTA neck with contrast | 2 | For treatment planning along with CTA of head. May identify arterial dissection as source of SAH (vertebral more likely than carotid). | ☢☢☢ |
| US carotid with Doppler | 1 | | O |
| US transcranial with Doppler | 1 | | O |
| MRI functional (fMRI) head without contrast | 1 | | O |
| MR spectroscopy head without contrast | 1 | | O |
| $^{15}$O-PET head | 1 | | ☢☢☢ |
| Tc-99m HMPAO SPECT head | 1 | | ☢☢☢☢ |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation Level |

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 8: Proven SAH by lumbar puncture or imaging.

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| Arteriography cervicocerebral | 8 | | ☢☢☢ |
| Arteriography neck | 8 | For treatment planning. As part of cerebral angiography. | ☢☢☢ |
| CT head without contrast | 8 | | ☢☢☢ |
| CTA head with contrast | 8 | | ☢☢☢ |
| MRA head without contrast | 7 | | O |
| MRA head without and with contrast | 7 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| MRI head without contrast | 6 | | O |
| MRI head without and with contrast | 6 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| MRA neck without contrast | 6 | | O |
| MRA neck without and with contrast | 6 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| CTA neck with contrast | 6 | For treatment planning. | ☢☢☢ |
| US transcranial with Doppler | 5 | For vasospasm. | O |
| CT head without and with contrast | 5 | | ☢☢☢ |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative |

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| CT head with contrast | 5 | | ☢☢☢ |
| US carotid with Doppler | 1 | | O |
| | | | |
| MRI functional (fMRI) head without contrast | 1 | | O |
| MR spectroscopy head without contrast | 1 | | O |
| $^{15}$O-PET head | 1 | | ☢☢☢ |
| Tc-99m HMPAO SPECT head | 1 | | ☢☢☢☢ |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation Level |

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 9: Proven SAH, negative angiogram, follow-up.

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| Arteriography cervicocerebral | 8 | | ☢☢☢ |
| MRI head without contrast | 8 | | O |
| MRI head without and with contrast | 8 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| MRA head without contrast | 8 | | O |
| MRA head without and with contrast | 8 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| CTA head with contrast | 8 | MRI preferred if treatment is not unreasonably delayed. | ☢☢☢ |
| US transcranial with Doppler | 5 | For vasospasm. | O |
| Arteriography neck | 5 | | ☢☢☢ |
| MRA neck without contrast | 5 | | O |
| MRA neck without and with contrast | 5 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| CT head without contrast | 5 | | ☢☢☢ |
| CT head with contrast | 5 | | ☢☢☢ |
| CT head without and with contrast | 5 | | ☢☢☢ |
| CTA neck with contrast | 5 | | ☢☢☢ |
| US carotid with Doppler | 1 | | O |
| MRI functional (fMRI) head without contrast | 1 | | O |
| MR spectroscopy head without contrast | 1 | | O |
| $^{15}$O-PET head | 1 | | ☢☢☢ |
| Tc-99m HMPAO SPECT head | 1 | | ☢☢☢☢ |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative |

| Radiologic Procedure | Rating | Comments | RRL* Radiation Level |
|---|---|---|---|

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 10: Clinically suspected parenchymal hemorrhage (hematoma), not yet confirmed.

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| CT head without contrast | 9 | | ☢☢☢ |
| CT head without and with contrast | 7 | | ☢☢☢ |
| CT head with contrast | 7 | | ☢☢☢ |
| MRI head without contrast | 6 | | O |
| MRI head without and with contrast | 6 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| MRA head without contrast | 4 | | O |
| MRA head without and with contrast | 4 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| CTA head with contrast | 4 | | ☢☢☢ |
| Arteriography cervicocerebral | 3 | | ☢☢☢ |
| MRA neck without contrast | 3 | | O |
| MRA neck without and with contrast | 3 | | O |
| CTA neck with contrast | 3 | | ☢☢☢ |
| Arteriography neck | 2 | | ☢☢☢ |
| US carotid with Doppler | 1 | | O |
| US transcranial with Doppler | 1 | | O |
| MRI functional (fMRI) head without contrast | 1 | | O |
| MR spectroscopy head without contrast | 1 | | O |
| $^{15}$O-PET head | 1 | | ☢☢☢ |
| Tc-99m HMPAO SPECT head | 1 | | ☢☢☢☢ |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation Level |

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 11: Proven parenchymal hemorrhage (hematoma)

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| MRI head without contrast | 8 | | O |
| MRI head without and with contrast | 8 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative |

| Radiologic Procedure | Rating | Comments | RRL* |
|---|---|---|---|
| MRA head without and with contrast | 8 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| CT head without contrast | 8 | Combined vascular and cerebral evaluation should be considered. MRI preferred if treatment is not unreasonably delayed. | ☢☢☢ |
| CTA head with contrast | 8 | Combined vascular and cerebral evaluation should be considered. MRI preferred if treatment is not unreasonably delayed. | ☢☢☢ |
| Arteriography neck | 7 | | ☢☢☢ |
| Arteriography cervicocerebral | 7 | If AVM suspected. | ☢☢☢ |
| CT head without and with contrast | 7 | | ☢☢☢ |
| CT head with contrast | 7 | | ☢☢☢ |
| MRA neck without contrast | 5 | | O |
| MRA neck without and with contrast | 5 | See statement regarding contrast in text under "Anticipated Exceptions." | O |
| CTA neck with contrast | 5 | | ☢☢☢ |
| US carotid with Doppler | 1 | | O |
| US transcranial with Doppler | 1 | | O |
| MRI functional (fMRI) head without contrast | 1 | | O |
| MR spectroscopy head without contrast | 1 | | O |
| $^{15}$O-PET head | 1 | | ☢☢☢ |
| Tc-99m HMPAO SPECT head | 1 | | ☢☢☢☢ |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation Level |

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Summary of Literature Review

Introduction/Background

Diseases of the cerebral vasculature are often manifested as stroke, a generic term encompassing a range of ischemic and hemorrhagic lesions (see Appendix 1 of the original guideline document). There are about 795,000 strokes per year in the United States (U.S.), an average of one every 40 seconds; of these 795,000 are new and 185,000 are recurrent. Stroke is the third leading underlying or contributing cause of death in the U.S. behind heart disease and cancer, accounting for one of every 18 (137,265) deaths in 2006, an average of one death every 3 to 4 minutes. The mean age of stroke death in 2002 was 79.6 years, and the overall death rate was 46.6 per 100,000 in 2005, a decline of 29.7% since 1995; 8%-12% of ischemic strokes and 37%-38% of hemorrhagic strokes result in death within 30 days. Of all strokes, 87% are ischemic, 10% are intracerebral hemorrhage, and 3% are subarachnoid hemorrhage (SAH). Significant functional disability is common in nonfatal cases, and stroke is a leading cause of serious, long-term disability in the U.S. Between 50%-70% of stroke survivors regain functional independence, but 15%-30% are permanently disabled, and 20% require institutional care at 3 months after onset. The estimated direct and indirect cost of stroke in the U.S. in 2009 was $68.9 billion.

Imaging and Stroke Risk

Because of the gravity of stroke's sequelae, considerable effort has been expended to identify risk factors for the disease (see Appendix 2 of the original guideline document) and strategies for stroke prevention in high-risk patients. These range from modification of lifestyle to surgical or

endovascular intervention. Surgery has been shown to be effective in reducing morbidity of both asymptomatic and symptomatic patients in randomized, prospective clinical trials in which the intent to treat was determined partly by imaging. In asymptomatic patients, screening should be undertaken not only by a sensitive, noninvasive (low-risk) test directed at identifying the abnormal cerebrovascular substrate but also with some consideration for identifying those in at-risk populations with a high prevalence of disease (e.g., patients with carotid bruit).

Although the diagnostic accuracies of duplex ultrasound (US), computed tomography angiography (CTA), magnetic resonance angiography (MRA), and time-resolved contrast-enhanced MRA (CE-MRA) are all high for internal carotid artery (ICA) stenosis, 70%-99%, only US appears to offer cost-effective initial screening. However, variability in performance (efficacy vs effectiveness), calcified plaque artifact, and difficulty distinguishing subtotal occlusion from total occlusion preclude endorsement of its routine use as the sole examination before endarterectomy. Combined use of US with CE-MRA is an increasingly common practice.

Multislice CTA is promising, but relatively few rigorous studies have been done, and the technique remains limited by the large intravenous (IV) contrast injection volumes required, the potential contrast toxicity or reaction, the radiation dose, and the plaque calcification that may obscure the stenosis. It should be noted that although surgical outcome studies have been based on catheter angiography, the possible morbidity of these studies and the continuing improvement in noninvasive examinations have made invasive studies less common, and it is unlikely that many rigorous comparison studies will be done in the future. The predictive value of carotid stenosis for symptomatic cerebral ischemia may be further improved by direct characterization of the atherosclerotic plaque. A variety of imaging strategies may be undertaken in symptomatic patients at risk for major ischemic stroke, where the initial studies can be directed toward the brain parenchyma, and a vascular study included immediately at the outset.

Elevated ischemic stroke risk in patients with chronic carotid stenosis or occlusion can also be identified by using single photon emission computed tomography (SPECT) and research xenon CT methods which show reduced cerebral vascular reserve (CVR) after acetazolamide challenge, or by elevated oxygen extraction fraction (OEF) using $^{15}$O-PET (positron emission tomography). Although there is limited experience with MR and CT perfusion (CTP) methods for this purpose, elevated cerebral blood volume (CBV) appears to correlate with reduced CVR and increased stroke risk, and these modalities are more widely available than PET.

Clinical Characteristics of Stroke

Clinically, stroke is most often characterized by the ictal onset of focal neurologic symptoms due to ischemia or hemorrhage into the brain. Ischemic infarction can be classified into various subgroups based on the mechanism of the ischemia (hemodynamic or thromboembolic) and the pathology of the vascular lesion: atherosclerotic, lacunar, cardioembolic, or indeterminate. The various stroke subtypes differ in cause, frequency, clinical signs, outcomes, and treatment, and are defined by diagnostic evaluation of etiology (ischemic vs hemorrhagic) and underlying vasculature. Intracranial hemorrhage can be subdivided into two distinct types based on the site and origin of blood: subarachnoid and intracerebral hemorrhage. Although stroke is typically acute in onset, occasionally the onset is less immediate and more gradual or stuttering. Differential diagnostic considerations in these cases include atypical migraine, multiple sclerosis, venous occlusive disease, and atypical epilepsy.

Thrombolytic Treatment

Current clinical practice in the U.S. is based on the 1996 U.S. Food and Drug Administration (FDA) approval of the thrombolytic agent recombinant tissue plasminogen activator (rtPA) given intravenously, preferably within 1 hour and no later than 3 hours after symptom onset, following exclusion of intracerebral hemorrhage by a noncontrast CT (NCCT) scan. The Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) has included these criteria in its requirements for Stroke Center designation. Recommendations also include acquisition of NCCT within 25 minutes of admission and expert interpretation within 20 minutes (45 minutes "door-to-interpretation" time). Recent increases in public awareness, faster emergency medical response, and establishment of dedicated stroke centers have resulted in 19%-60% of admissions arriving at treatment centers within 3 hours of symptom onset. However, following appropriate medical exclusions, successful treatment with rtPA, without symptomatic major hemorrhage, is limited to 3%-8.5% of ischemic stroke admissions. The effectiveness of IV thrombolysis treatment does not appear to vary by stroke subtype (embolic, atherosclerotic, small-vessel occlusion). There is growing evidence that intra-arterial (IA) thrombolytic delivery or mechanical clot extraction methods are effective alone or with IV rtPA in the specific clinical circumstances of later presentation, large-vessel occlusion, and larger clot burden. However, hemorrhagic risk may be somewhat higher, and organizational complexity has limited widespread use of these methods in general practice and may delay treatment delivery.

Transient Ischemic Attack

Traditionally, if focal neurologic symptoms continued for more than 24 hours, stroke was diagnosed; otherwise, a focal neurologic deficit lasting less than 24 hours was defined as a transient ischemic attack (TIA). However, this time-based definition of TIA may be inadequate and misleading, potentially leading to inappropriate delays in diagnosis and treatment. A "tissue-based" definition has been proposed that considers all acute focal neurologic deficits as possible infarcts and classifies them as "acute neurovascular syndromes" or "acute ischemic cerebrovascular syndromes" (AICS) based on the degree of certainty of tissue ischemic injury, which is determined primarily by tissue and vascular imaging studies. Because

most transient ischemic neurologic symptoms (70%) last for 2 hours or less and 30%-50% show tissue injury on MRI diffusion-weighted imaging (DWI), the American Stroke Association (ASA) has recently proposed a new definition of TIA as "a transient episode of neurological dysfunction caused by focal brain, spinal cord, or retinal ischemia, without acute infarction." This change reflects the growing emphasis on the earliest possible diagnosis and treatment of acute ischemia and the use of NCCT for exclusion of hemorrhage and MRI for definitive infarct diagnosis. However, based on the current FDA recommendations, only the presence of acute hemorrhage on NCCT is a contraindication to rtPA treatment in the first 3 hours after ictus. The absence of DWI changes may not justify withholding rtPA, even in the setting of rapidly improving symptoms in the first 3 hours, because treatment may result in good outcome and as many as a third of these patients go on to subsequent severe deterioration if not treated. In addition, because 10%-15% of all strokes are heralded by a TIA within 90 days, half within 48 hours, a history of recent TIA should trigger an immediate workup for stroke risks and follow-up tissue and vascular imaging studies.

Magnetic Resonance Imaging

Rapid and accurate diagnosis of ischemia, completed infarction, and hemorrhage has become paramount in importance for treating acute cerebrovascular disease because of the demonstrable benefit (and hemorrhage risk) of acute IV and IA thrombolytic therapy for cerebral ischemia in prospective clinical trials. MRI in the form of DWI has been shown to be exquisitely sensitive to acute infarction within minutes of the precipitating ictus, with sensitivity of 88%-100% compared to NCCT's mean sensitivity of 66% (range 20%-87%). The specificity of DWI for ischemic injury is also high (95%-100%), although small reductions in apparent diffusion coefficient (ADC) (e.g., 20% below normal) can represent reversible ischemia that may not progress to completed infarct. Additional information obtainable through the combined use of dynamic CBV techniques (perfusion-weighted imaging [PWI] as well as vascular imaging [MRA]) makes MRI an appealing tool for diagnosis and treatment monitoring of acute cerebrovascular disease.

However, enthusiasm for MRI in the setting of acute stroke has been tempered by the variable and confounding appearance of hemorrhage. Intracranial hemorrhage can be recognized and characterized by MRI findings if one considers: 1) the location, specifically subarachnoid vs intraparenchymal; 2) the oxidative state of hemoglobin and the subsequent breakdown products; 3) the type of imaging pulse sequence used (T1 vs T2, spin-echo vs gradient-echo, conventional spin-echo vs rapid-acquisition relaxation-enhanced [RARE] sequences); and 4) the field strength of the machine used to acquire the images. Recent experience using T2* (gradient-echo) imaging to detect low-signal parenchymal hemorrhage (ICH) and FLAIR (fluid-attenuated inversion recovery) scans to detect high-signal SAH have helped to renew interest in MRI as a first-line modality in patients with acute, focal neurologic deficits. However, because the high signal in sulci on FLAIR images is not specific for hemorrhage and may be seen with meningitis, elevated protein, gadolinium passage through the blood-brain barrier, and even oxygen therapy with anesthesia, CT continues to be recommended for routine exclusion and specific identification of SAH.

Although the FDA approval for rtPA includes the language "exclusion of intracranial hemorrhage by cranial CT or other diagnostic imaging method sensitive to the presence of hemorrhage" and parenchymal microhemorrhages on gradient echo MRI, not visible on CT, may better predict hemorrhagic complications of rtPA therapy, there is currently insufficiently widespread clinical experience to recommend MRI over CT for routine exclusion of ICH or to withhold rtPA therapy in the presence of microhemorrhages on MRI within he first 3 hours after ictus. It is also important to emphasize the issue of availability of MRI in the context of the 3-hour therapeutic window, the difficulty of managing medically unstable patients in the MRI machine, and potential contraindications: patients with pacemakers, cerebral aneurysm clips, ocular foreign bodies, or cochlear implants and those suffering from claustrophobia or morbid obesity (>320 pounds).

Because of the small percentage of acute stroke patients treated within the 3-hour limit, there is growing interest in expanding the treatment window without increasing hemorrhage risk. A pooled risk-benefit analysis of existing rtPA trials using NCCT scan exclusion of hemorrhage has suggested that treatment may be safe in some patients out to 4.5 hours after ictus, but FDA and ASA recommendations have not yet been modified to include this expanded treatment window in published guidelines. In addition, several current clinical trials are focused on the use of thrombolytic and neuroprotective agents combined with MRI techniques to expand the treatment window by identifying the "ischemic penumbra," the underperfused yet viable halo of brain parenchyma around or interspersed with the region of completed infarction that is at risk of progressing to infarction. Gadolinium bolus dynamic susceptibility contrast (DSC) MRI-PWI measures tissue blood flow parameters (cerebral blood flow, CBV, mean transit time [MTT], and time to peak [TTP]) based on the central volume principle and is being used to identify the volume of tissue with reduced blood flow, which is then compared to the volume of presumed infarcted tissue as indicated by restricted diffusion (reduced ADC on DWI). When the low-blood-flow tissue volume is larger than the restricted diffusion volume by 20% or more, a perfusion-diffusion (PWI-DWI) "mismatch" is said to exist.

Multiple MRI approaches have been suggested using several analyses of diffusion restriction and measures of abnormal perfusion, including arterial spin labeling (ASL), to characterize the mismatch and its predictive value for final infarct volume. MRI PWI-DWI mismatch is being used as a surrogate "biomarker" for the treatment decisions at time points from 3 to 24 hours after ictus in several ongoing thrombolysis and mechanical clot extraction trials. These trials are based on the intuitively attractive concept of determining treatment based on the physiologic status of the ischemic brain tissue rather than only on the time since symptom onset. Results have been mixed, with some trials showing successful treatment as late as 9

hours after ictus without increased incidence of symptomatic hemorrhage and others showing marginal or no clinical improvement. Currently there is neither sufficient scientific evidence nor widespread clinical experience to recommend these diagnostic approaches for routine thrombolytic treatment beyond the 3-hour window after symptom onset.

A limitation of the MRI mismatch approach is that it may overestimate the true penumbra and not specifically identify tissue at risk of infarction. The low blood flow in the mismatch zone outside the restricted diffusion infarct core may include underperfused but metabolically stable oligemic tissue which is likely to survive with the existing perfusion level, as well as unstable penumbral tissue that is likely to become infarct if reperfusion therapy is delayed or ineffective. Oligemic and penumbral regions can be more precisely identified by measuring oxygen metabolism ($CMRO_2$) and the OEF, both of which are maintained at normal levels in stage I ischemia of the oligemic region. Normal or slightly reduced $CMRO_2$ and elevation of the OEF are present in stage II ischemia or "misery perfusion" in the penumbral region. Regions of positive DWI with restricted diffusion may also contain potentially salvageable zones of penumbral tissue. Images of oxygen metabolism can be acquired using $^{15}$O-PET or experimental MRI methods, and images of hypoxemic tissue can be obtained with $^{18}$F-fluoromisonidazole positron emission tomography ($^{18}$FMISO-PET), but these imaging techniques are not currently available in general clinical practice.

Proton MR spectroscopy of acute ischemia shows reduction in N-acetyl aspartate (NAA), indicating neuronal dysfunction and/or cell loss, and elevation of lactate, indicating a shift to anaerobic glycolysis with tissue oxygen deprivation. NAA may be preserved in regions of acute diffusion restriction (which also includes glial cell injury), and lactate elevation may be seen within and around the diffusion abnormality, suggesting that the NAA/lactose ratio may be a biomarker of a potentially treatable "neuronal" ischemic penumbra. Creatine and choline levels are variable. Creatine may be depressed with depletion of energy metabolites, and choline may be elevated with membrane breakdown during necrosis and macrophage inflammatory response. In addition, a progressive decline in NAA for up to 2 weeks after ictus may indicate ongoing pathologic processes such as apoptosis or inflammation that can provide a treatment target for neuronal rescue in subacute stroke. However, in general clinical practice, proton magnetic resonance spectroscopy (MRS) has limited application in acute diagnosis and management or in predicting long-term disability with ischemic stroke.

Functional MRI (blood oxygen level dependent [BOLD] fMRI) and diffusion tensor imaging (DTI) are being applied to the assessment of stroke recovery in many research centers. The emphasis has been on motor recovery, with fewer studies of language and cognitive functional recovery. fMRI of acute ischemia has demonstrated dynamic cerebral plasticity with early expansion of the area of brain activation and early reorganization of the functional map to the contralesional hemisphere (same side as the limb motor deficit), followed by partial return to the preictal activation pattern with recovery of motor function. Evidence is growing in support of fMRI as a predictor of eventual functional recovery and as a monitor of rehabilitative therapy. However, these studies must be interpreted with caution because BOLD fMRI is dependent on blood flow changes, and the absence of activation may not indicate the absence of neuronal activity in regions of hemodynamic compromise. DTI fractional anisotropy (FA) and tractography are dependent on directional water diffusion along white matter tracts and are being explored as biomarkers of axonal and myelin integrity. Acute white matter FA reductions of greater severity and duration have been shown to negatively correlate with functional recovery, and progressive reductions in FA and reduced white matter tract mapping are seen with Wallerian degeneration. The combined use of DTI and fMRI may improve overall prediction of functional recovery, but there has not been sufficiently widespread clinical experience with these techniques to endorse them as reliable clinical tools.

Computed Tomography

With the introduction of CT scanning by Hounsfield in the early 1970s came the ability to acutely assess the brain, subarachnoid, and ventricular spaces noninvasively. Similarly, on the basis of the x-ray attenuation of blood and edema relative to cerebrospinal fluid (CSF) and brain parenchyma, CT is effective in detecting acute hemorrhage into brain parenchyma and the subarachnoid, subdural, or intraventricular spaces, and in distinguishing acute hemorrhage from ischemia/infarction. On the basis of ready availability and high sensitivity to the presence or absence of acute blood, NCCT historically has been the preferred modality for initial imaging of suspected stroke but has lacked a similar sensitivity to acute ischemia and infarction. The relatively low sensitivity of NCCT to early ischemic injury (only one-third to two-thirds of lesions detected in various studies) and the variable quantitation and interpretation of ischemic changes have limited its use in early stroke management. Further studies are needed to determine the value of scoring systems and the significance of low-density changes, such as infarct size greater than one-third of the middle cerebral artery territory, to early stroke decision making. It is not recommended that these findings be used to withhold rtPA thrombolytic treatment within the first 3 hours after symptom onset.

A recent resurgence in the use of CT for initial stroke evaluation has occurred with the increasing clinical availability of CTP and CTA. CTP is acquired by rapid scanning during a bolus IV contrast infusion, and blood flow parameters (CBF, CBV, MTT, and TTP) are calculated based on the central volume principle. This has transformed CT into a technique with high sensitivity to cerebrovascular abnormalities and early perfusion deficits, detectable prior to observable low-density changes on NCCT. Quantitative CTP measurements of CBF parameters have been proposed as a means of discriminating between infarct and penumbra and have been compared favorably to MRI. These measurements, plus the ability to

quickly identify acute hemorrhage and vascular occlusive lesions as well as the ubiquitous availability of CT scanners, have been suggested as the key advantages of CT over MRI for acute stroke evaluation. The limited volume coverage of current multidetector CT scanners (2 or 4 cm wide slab in the z-axis, the width of the detector array) has been a disadvantage compared to the whole-brain coverage of MRI, but the use of two contrast injections and "shuttle" mode scanning to double the coverage volume and the recent introduction of a new generation of CT scanners with 8 to 16 cm wide detector arrays will allow larger brain volume or whole-brain CTP studies more routinely in the future. However, greater risks of renal toxicity, contrast reaction, or fluid overload from iodinated contrast materials vs gadolinium, the variability in CTP quantitative methods, and the lack of a direct measure of cellular viability such as diffusion restriction mitigate these advantages over MRI.

Acute Stroke and Advanced Imaging

It should be emphasized that the current FDA-approved treatment for acute ischemic stroke symptoms is IV rtPA within 3 hours of symptom onset and that the recommended imaging study is an NCCT to exclude acute hemorrhage. The multimodality MRI and CT studies described above may be useful to confirm the stroke diagnosis and subtype, demonstrate lesion location, identify vascular occlusion, and guide other management decisions within and beyond the 3-hour period. But the ASA guidelines and others specifically recommend that emergency IV rtPA treatment within the first 3 hours after ictus not be delayed in order to obtain multimodality imaging studies and that treatment not be withheld on the basis of either positive or negative MRI or CT findings, other than acute hemorrhage on the NCCT.

Subarachnoid Hemorrhage

Because CT is highly specific and sensitive to the presence or absence of acute blood it has been the mainstay in emergent evaluation of acute intracranial hemorrhage, especially subarachnoid or parenchymal hemorrhage, which is associated with high morbidity and mortality. In the case of aneurysmal SAH, this is partly due to the relatively high rate of early rebleeding. In patients presenting with SAH, early surgery or coiling is offered as a strategy to circumvent this problem, which in turn requires early cerebral angiography. IA catheter angiography's sensitivity to cerebral aneurysms is estimated to be greater than 90%; in the setting of acute SAH this figure decreases to slightly greater than 80%. Initial IA angiography may be negative in 10%-20% of cases because of small aneurysm size, aneurysm thrombosis, local vasospasm, or an incomplete study, and repeat angiography has traditionally been recommended within 1 to 2 weeks. However, the cost and risk versus benefit of the additional 1%-2% diagnostic yield has been debated.

Recent clinical practice has shifted toward use of NCCT for SAH detection followed immediately by CTA for aneurysm detection. Comparisons between CTA and catheter angiography in SAH patients, beginning with single-slice methods and more recently with multislice methods, have shown overall aneurysm detection sensitivities of 85%-95%, lower for smaller aneurysms to approximately 50% for those <2 mm in diameter. Treatment of intracranial aneurysms following SAH is increasingly based on CTA alone. The late appearance of new neurological changes suggestive of post-SAH vasospasm, ischemia, or hydrocephalus is increasingly investigated with transcranial Doppler (TCD) and CT imaging with CTA and CTP, while catheter angiography and SPECT are being used less frequently than in the past.

Follow-up of Treated Aneurysms

Treatment of intracranial aneurysms has evolved in recent years toward more use of endovascular coil embolization, in place of or combined with surgical clipping. In Europe, a prospective randomized multicenter trial comparing clipping and coiling in 2,143 patients with ruptured intracranial aneurysms suitable for both treatments demonstrated that endovascular coiling was more likely to result in independent survival at 1 year than neurosurgical clipping. Follow-up of treated aneurysms, clipped or coiled, to identify residual filling is done definitively with catheter digital subtraction angiography (DSA) but there is a growing interest in the use of less invasive techniques. CTA is inherently limited for this purpose because of the prominent "star" artifact produced by aneurysm clips and even more by the aneurysm coil mass. Time-of-flight (TOF) MRA for this purpose is increasingly popular but is limited by local susceptibility and spin dephasing artifacts from the clip or coils and by turbulent flow and T1 saturation signal loss. Dynamic CE-MRA using bolus gadolinium injection and short TE ellipticocentric time-resolved acquisitions (e.g., TRICKS) produces less susceptibility artifact and dephasing with reduced venous contamination of the arterial signal. However, at this point the findings of the small studies are not sufficiently conclusive to recommend routine CE-MRA for post-treatment aneurysm follow-up. Most of these studies were performed at 1.5 T, but experience at 3 T suggests better results with TOF-MRA, CE-MRA, and postcontrast volumetric techniques and favorable correlation with catheter DSA. Before imaging at 3.0 T, safety clearance for specific devices should be obtained from published sources or the device manufacturer.

Aneurysm Screening

Because of the cumulative long-term risk of morbidity and mortality from SAH, especially with larger aneurysms (>25 mm in diameter) and the relatively low risks of clipping or coiling unruptured intracranial aneurysms, there may be a clinical role for prophylactic screening. IA angiography carries the risk of thromboembolic complication and is relatively expensive; MRI and CTA are less expensive, noninvasive alternatives, although their sensitivity to lesions <5 mm in diameter is suspect. To date, individuals with a history of aneurysm or SAH in a first-degree relative have been considered candidates for screening. Nevertheless, significant gaps in knowledge of the natural history (and thus risk of rupture) of intracranial

aneurysms remain. Hence, while screening with MRA or CTA may be appropriate in patients with a positive family history, its impact on patient outcome is questionable.

Vascular Malformations

Parenchymal brain hemorrhage may be associated with underlying vascular malformations such as arteriovenous malformations (AVMs), pial arteriovenous fistulae, and cavernous malformations in younger patients, as well as dural fistulae in older individuals. Diagnosis, assessment of risk for future hemorrhage, and effective treatment planning are all predicated on determination of the size of the underlying lesion, location within the brain parenchyma, pattern of venous drainage, and presence of intranidal aneurysm. Acutely, this information is most frequently obtained by IA angiography, which in more complicated cases may be supplemented by MRI to assess underlying tissue injury. Although time-resolved ellipticocentric bolus contrast CE-MRA techniques with multicoil sensitivity encoding currently have temporal resolution in the 1-2-second range, they do not yet rival catheter DSA arteriography for separation of arterial and venous phases of high-flow AVMs. However, they may be useful for follow-up of partially embolized lesions. Baseline and follow-up MRI may be appropriate in partially embolized cases or in patients undergoing stereotactic radiosurgery as noninvasive, low-risk means of identifying ischemic complications and assessing response to therapy. CTA on newer generation dual-source, flat-panel, and wide-detector scanners may provide adequate temporal resolution for noninvasive evaluation of AVMs.

Assumptions

All patient scenarios should be addressed as though the patients had been referred for imaging following a history and physical examination that included neurological, vascular, and ophthalmoscopic examinations.

Summary

- Stroke is the sudden onset of focal neurologic symptoms due to ischemia or hemorrhage in the brain. It occurs 795,000 times each year in the U.S. and is the third leading cause of death, behind heart disease and cancer.
- Assessment of stroke risk with imaging techniques increasingly involves noninvasive vascular imaging and functional evaluation of CBF and metabolism.
- Current FDA-approved clinical treatment of acute ischemic stroke involves the use of the IV thrombolytic agent rtPA given within 3 hours after symptom onset, following exclusion of intracerebral hemorrhage by a NCCT scan.
- TIAs typically last 2 hours or less (70%), are positive for ischemic injury on DWI in 30%-50% of cases, and should be fully evaluated for stroke risk because 10%-15% of strokes are heralded by a TIA.
- MRI DWI is highly sensitive and specific for acute cerebral ischemia and, when combined with PWI, may be used to identify potentially salvageable ischemic tissue, especially in the period greater than 3 hours after symptom onset.
- MRI identification of acute intracranial hemorrhage may be variable and nonspecific. Although MRI is potentially more sensitive than CT, it is not generally used as a substitute for CT to detect acute intracranial hemorrhage.
- Advanced MRI and other metabolic imaging techniques may improve acute cerebral ischemia evaluation and assessment of long-term disability but are not currently used in general clinical practice.
- NCCT is preferred for initial imaging of acute stroke based on its wide availability and high sensitivity to acute hemorrhage, although it is relatively insensitive to acute ischemia and infarction (only one-third to two-thirds of lesions are detected).
- Advanced CTP methods improve sensitivity to acute ischemia and are increasingly used with CTA to evaluate acute stroke as a supplement the NCCT.
- Advanced MRI, CT, and other techniques may confirm the stroke diagnosis and subtype, demonstrate lesion location, identify vascular occlusion, and guide other management decisions but, within the first 3 hours after ictus, should not delay or be used to withhold rtPA therapy after the exclusion of acute hemorrhage on the NCCT scans.
- NCCT is also the mainstay of acute SAH diagnosis and, although catheter IA angiography is definitive, there is increasing use of CTA for imaging arterial aneurysms as the source of hemorrhage. CTA and MRA are also increasingly used to screen for asymptomatic aneurysms and for follow-up of treated aneurysms.
- Catheter IA angiography is the definitive technique for diagnosing intracranial and spinal vascular malformations, typically combined with endovascular treatment, but new rapid-acquisition CTA and MRA techniques show promise as alternative diagnostic imaging methods.

Anticipated Exceptions

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (i.e., <30 mL/min/1.73 $m^2$), and almost never in other patients. There is growing literature regarding NSF. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible

benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73 $m^2$. For more information, please see the American College of Radiology (ACR) Manual on Contrast Media (see the "Availability of Companion Documents" field).

Abbreviations

- 3D, 3-dimensional
- ASA, American Stroke Association
- ASL, arterial spin labeling
- AVM, arteriovenous malformation
- CE-MRA, contrast-enhanced magnetic resonance angiography
- $CMRO_2$, cerebral metabolic rate of oxygen
- CT, computed tomography
- CTA, computed tomography angiography
- CTP, computed tomography perfusion
- CVR, cerebrovascular reserve
- DSC, dynamic susceptibility contrast
- DWI, diffusion-weighted imaging
- FDA, U.S. Food and Drug Administration
- FLAIR, fluid-attenuated inversion recovery
- fMRI, functional magnetic resonance imaging
- HMPAO, hexamethylpropyleneamine oxime
- ICA, internal carotid artery
- JCAHO, Joint Commission on the Accreditation of Healthcare Organizations
- MRA, magnetic resonance angiography
- MRI, magnetic resonance imaging
- NCCT, noncontrast computed tomography
- OEF, oxygen extraction fraction
- PET, positron emission tomography
- PWI, perfusion-weighted imaging
- rtPA, recombinant tissue plasminogen activator
- SAH, subarachnoid hemorrhage
- SPECT, single photon-emission computed tomography
- Tc, technetium
- TOF, time-of-flight
- TIA, transient ischaemic attack
- US, ultrasound

Relative Radiation Level Designations

| Relative Radiation Level* | Adult Effective Dose Estimate Range | Pediatric Effective Dose Estimate Range |
|---|---|---|
| O | 0 mSv | 0 mSv |
| ☢ | <0.1 mSv | <0.03 mSv |
| ☢☢ | 0.1-1 mSv | 0.03-0.3 mSv |
| ☢☢☢ | 1-10 mSv | 0.3-3 mSv |
| ☢☢☢☢ | 10-30 mSv | 3-10 mSv |
| ☢☢☢☢☢ | 30-100 mSv | 10-30 mSv |
| *RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies". | | |

## Clinical Algorithm(s)

Algorithms were not developed from criteria guidelines.

# Scope

## Disease/Condition(s)

Cerebrovascular disease, including:

- Acute ischemic cerebrovascular syndrome
- Transient ischemic attack
- Stroke
- Cerebral (ischemic) infarction
- Hemorrhagic infarction
- Parenchymal hemorrhage (hematoma)
- Subarachnoid hemorrhage
- Intracranial aneurysm
- Vascular malformation

## Guideline Category

Diagnosis

Evaluation

Risk Assessment

## Clinical Specialty

Emergency Medicine

Family Practice

Internal Medicine

Neurological Surgery

Neurology

Radiology

## Intended Users

Health Plans

Hospitals

Managed Care Organizations

Physicians

Utilization Management

## Guideline Objective(s)

To evaluate the appropriateness of initial radiologic examinations for patients with cerebrovascular disease

## Target Population

Patients with cerebrovascular disease

## Interventions and Practices Considered

1. Ultrasound (US)
    - Carotid with Doppler
    - Transcranial with Doppler
2. Magnetic resonance angiography (MRA)
    - Neck without contrast
    - Neck without and with contrast
    - Head without contrast
    - Head without and with contrast
    - Head and neck without contrast
    - Head and neck without and with contrast
3. Computed tomography angiography (CTA)
    - Neck with contrast
    - Head with contrast
    - Head and neck with contrast
4. Magnetic resonance imaging (MRI)
    - Head without contrast
    - Head without and with contrast
5. Computed tomography (CT)
    - Head without contrast
    - Head with contrast
    - Head without and with contrast
    - Head perfusion with contrast
6. Arteriography
    - Neck
    - Cervicocerebral
7. Magnetic resonance (MR) spectroscopy head without contrast
8. $^{15}$O-positron emission tomography (PET) head
9. Technetium (Tc)-99m hexamethylpropyleneamine-oxime (HMPAO) single-photon-emission computed tomography (SPECT) head
10. Functional magnetic resonance imaging (fMRI) head without contrast

## Major Outcomes Considered

- Utility of radiologic examinations in differential diagnosis
- Mortality rate

# Methodology

## Methods Used to Collect/Select the Evidence

Searches of Electronic Databases

## Description of Methods Used to Collect/Select the Evidence

Literature Search Procedure

The Medline literature search is based on keywords provided by the topic author. The two general classes of keywords are those related to the condition (e.g., ankle pain, fever) and those that describe the diagnostic or therapeutic intervention of interest (e.g., mammography, MRI).

The search terms and parameters are manipulated to produce the most relevant, current evidence to address the American College of Radiology Appropriateness Criteria (ACR AC) topic being reviewed or developed. Combining the clinical conditions and diagnostic modalities or therapeutic procedures narrows the search to be relevant to the topic. Exploding the term "diagnostic imaging" captures relevant results for diagnostic topics.

The following criteria/limits are used in the searches.

1. Articles that have abstracts available and are concerned with humans.
2. Restrict the search to the year prior to the last topic update or in some cases the author of the topic may specify which year range to use in the search. For new topics, the year range is restricted to the last 5 years unless the topic author provides other instructions.
3. May restrict the search to Adults only or Pediatrics only.
4. Articles consisting of only summaries or case reports are often excluded from final results.

The search strategy may be revised to improve the output as needed.

## Number of Source Documents

The total number of source documents identified as the result of the literature search is not known.

## Methods Used to Assess the Quality and Strength of the Evidence

Weighting According to a Rating Scheme (Scheme Given)

## Rating Scheme for the Strength of the Evidence

Strength of Evidence Key

Category 1 - The conclusions of the study are valid and strongly supported by study design, analysis and results.

Category 2 - The conclusions of the study are likely valid, but study design does not permit certainty.

Category 3 - The conclusions of the study may be valid but the evidence supporting the conclusions is inconclusive or equivocal.

Category 4 - The conclusions of the study may not be valid because the evidence may not be reliable given the study design or analysis.

## Methods Used to Analyze the Evidence

Systematic Review with Evidence Tables

## Description of the Methods Used to Analyze the Evidence

The topic author drafts or revises the narrative text summarizing the evidence found in the literature. American College of Radiology (ACR) staff draft an evidence table based on the analysis of the selected literature. These tables rate the strength of the evidence for all articles included in the narrative text.

The expert panel reviews the narrative text, evidence table, and the supporting literature for each of the topic-variant combinations and assigns an appropriateness rating for each procedure listed in the table. Each individual panel member forms his/her own opinion based on his/her interpretation of the available evidence.

More information about the evidence table development process can be found in the ACR Appropriateness Criteria® Evidence Table Development document (see the "Availability of Companion Documents" field).

## Methods Used to Formulate the Recommendations

Expert Consensus (Delphi)

## Description of Methods Used to Formulate the Recommendations

Modified Delphi Technique

The appropriateness ratings for each of the procedures included in the Appropriateness Criteria topics are determined using a modified Delphi methodology. A series of surveys are conducted to elicit each panelist's expert interpretation of the evidence, based on the available data, regarding the appropriateness of an imaging or therapeutic procedure for a specific clinical scenario. American College of Radiology (ACR) staff distributes surveys to the panelists along with the evidence table and narrative. Each panelist interprets the available evidence and rates each procedure. The surveys are completed by panelists without consulting other panelists. The ratings are a scale between 1 and 9, which is further divided into three categories: 1, 2, or 3 is defined as "usually not appropriate"; 4, 5, or 6 is defined as "may be appropriate"; and 7, 8, or 9 is defined as "usually appropriate." Each panel member assigns one rating for each procedure per survey round. The surveys are collected and the results are tabulated, de-identified and redistributed after each round. A maximum of three rounds are conducted. The modified Delphi technique enables each panelist to express individual interpretations of the evidence and his or her expert opinion without excessive bias from fellow panelists in a simple, standardized and economical process.

Consensus among the panel members must be achieved to determine the final rating for each procedure. Consensus is defined as eighty percent (80%) agreement within a rating category. The final rating is determined by the median of all the ratings once consensus has been reached. Up to three ratings rounds are conducted to achieve consensus.

If consensus is not reached, the panel is convened by conference call. The strengths and weaknesses of each imaging procedure that has not reached consensus are discussed and a final rating is proposed. If the panelists on the call agree, the rating is proposed as the panel's consensus. The document is circulated to all the panelists to make the final determination. If consensus cannot be reached on the call or when the document is circulated, "No consensus" appears in the rating column and the reasons for this decision are added to the comment sections.

## Rating Scheme for the Strength of the Recommendations

Not applicable

## Cost Analysis

The guideline developers reviewed published cost analyses.

## Method of Guideline Validation

Internal Peer Review

## Description of Method of Guideline Validation

Criteria developed by the Expert Panels are reviewed by the American College of Radiology (ACR) Committee on Appropriateness Criteria.

# Evidence Supporting the Recommendations

## Type of Evidence Supporting the Recommendations

The recommendations are based on analysis of the current literature and expert panel consensus.

# Benefits/Harms of Implementing the Guideline Recommendations

## Potential Benefits

Selection of appropriate radiologic imaging procedures for evaluation of patients with acute cerebrovascular disease

## Potential Harms

Risks of renal toxicity, contrast reaction, or fluid overload from iodinated contrast materials

Gadolinium-Based Contrast Agents

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (i.e., <30 mL/min/1.73 m2), and almost never in other patients. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73 m2. For more information, please see the American College of Radiology (ACR) Manual on Contrast Media (see the "Availability of Companion Documents" field).

Relative Radiation Level (RRL)

Computed tomography (CT) stroke protocols combining a brain noncontrast CT (NCCT), CT angiography (CTA) and CT perfusion (CTP) may produce an RRL of ☢☢☢, and repeated use of this protocol in an individual patient may result in high radiation exposure (e.g., RRL of ☢☢☢☢) to the scalp and eyes.

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults. Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document (see the "Availability of Companion Documents" field).

# Contraindications

## Contraindications

- Based on the current U.S. Food and Drug Administration (FDA) recommendations, only the presence of acute hemorrhage on noncontrast computed tomography (NCCT) is a contraindication to recombinant tissue plasminogen activator (rtPA) treatment in the first 3 hours after ictus.
- Potential contraindications to magnetic resonance imaging: patients with pacemakers, cerebral aneurysm clips, ocular foreign bodies, or cochlear implants and those suffering from claustrophobia or morbid obesity (>320 pounds)

# Qualifying Statements

## Qualifying Statements

The American College of Radiology (ACR) Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the U.S. Food and Drug Administration (FDA) have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

# Implementation of the Guideline

## Description of Implementation Strategy

An implementation strategy was not provided.

# Institute of Medicine (IOM) National Healthcare Quality Report Categories

## IOM Care Need

Getting Better

Living with Illness

## IOM Domain

Effectiveness

Timeliness

# Identifying Information and Availability

## Bibliographic Source(s)

De La Paz RL, Wippold FJ II, Cornelius RS, Amin-Hanjani S, Angtuaco EJ, Broderick DF, Brown DC, Creasy JL, Davis PC, Garvin CF, Hoh BL, McConnell CT Jr, Mechtler LL, Seidenwurm DJ, Smirniotopoulos JG, Tobben PJ, Waxman AD, Zipfel GJ, Expert Panel on Neurologic Imaging. ACR Appropriateness CriteriaÂ® cerebrovascular disease. [online publication]. Reston (VA): American College of Radiology (ACR); 2011. 23 p. [131 references]

## Adaptation

Not applicable: The guideline was not adapted from another source.

## Date Released

1996 (revised 2011)

## Guideline Developer(s)

American College of Radiology - Medical Specialty Society

## Source(s) of Funding

The American College of Radiology (ACR) provided the funding and the resources for these ACR Appropriateness Criteria®.

## Guideline Committee

Committee on Appropriateness Criteria, Expert Panel on Neurologic Imaging

## Composition of Group That Authored the Guideline

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## Financial Disclosures/Conflicts of Interest

Not stated

## Guideline Status

Note: This guideline has been updated. The National Guideline Clearinghouse (NGC) is working to update this summary.

## Guideline Availability

Updated guideline available from the American College of Radiology (ACR) Web site .

Print copies: Available from the American College of Radiology, 1891 Preston White Drive, Reston, VA 20191. Telephone: (703) 648-8900.

## Availability of Companion Documents

The following are available:

- ACR Appropriateness Criteria®. Overview. Reston (VA): American College of Radiology; 2 p. Electronic copies: Available in Portable Document Format (PDF) from the American College of Radiology (ACR) Web site .
- ACR Appropriateness Criteria®. Literature search process. Reston (VA): American College of Radiology; 1 p. Electronic copies: Available in Portable Document Format (PDF) from the ACR Web site .
- ACR Appropriateness Criteria®. Evidence table development – diagnostic studies. Reston (VA): American College of Radiology; 2013 Nov. 3 p. Electronic copies: Available in PDF from the ACR Web site .
- ACR Appropriateness Criteria®. Radiation dose assessment introduction. Reston (VA): American College of Radiology; 2 p. Electronic copies: Available in Portable Document Format (PDF) from the ACR Web site .
- ACR Appropriateness Criteria® Manual on contrast media. Reston (VA): American College of Radiology; 90 p. Electronic copies: Available in PDF from the ACR Web site .
- ACR Appropriateness Criteria® cerebrovascular disease. Evidence table. Reston (VA): American College of Radiology; 2011. 27 p.

Electronic copies: Available from the ACR Web site .

## Patient Resources

None available

## NGC Status

This summary was completed by ECRI on July 31, 2001. The information was verified by the guideline developer as of August 24, 2001. This NGC summary was updated by ECRI Institute on April 26, 2007. This NGC summary was updated by ECRI Institute on December 10, 2010 and September 16, 2011.

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